E-GOVERNMENT DEVELOPMENT INDEX AND ITS COMPARISON IN THE EU MEMBER STATES

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Abstract: *This paper deals with a comparison of the e-Government development index, which is presented by the United Nations since 2003, usually every two years. It compares and describes the progress of this index between the years 2008 and 2014 in the European Union Member States in the context of the economic decline and the global recession. It also considers factors contributing to successful e-Government implementation, such as unemployment or inflation rate. The purpose of the submitted research study is to identify the influence of the selected macroeconomic indicators on the e-Government development index. The methodology of this research study comprised bibliographic studies, analysis of specialised reports, statistical analyses and evaluations. The main methods used were descriptive, correlation and the cluster analysis, which was in this case represented by the connectivity model (hierarchical clustering) as well as the centroid model (K-means clustering). The findings confirmed that the global recession and the Eurozone crisis have influenced the progress of the e-Government in the evaluated years. This research study provides insights that may be useful in improving the implementation of e-Government services.*

Keywords: *E-Government, Public sector, Cluster analysis, European Union.*

JEL Classification: *C38, H11, H83, L86.*

Introduction

With the trend of cost savings in the public sector, the electronic government or just e-Government is one of the possible options to operate more efficiently, effectively and transparently, to provide better, cheaper and faster services and open data to the public and to facilitate the participation of citizens and businesses in the governance. In March 2010 the European Commission launched the Europe 2020 Strategy [4] in view to exit the financial crisis and prepare the European Union (EU) economy for the challenges of the next decade. The Digital Agenda for Europe is one of the seven flagship initiatives of the Europe 2020 Strategy, defining the key enabling role that the use of Information and Communication Technologies (ICT) will have to play if Europe wants to succeed in its ambitions for 2020 [3], [4].

More broadly, e-Government can be referred to as the use and application of ICT in the public administration to streamline and integrate workflows and processes, to effectively manage data and information, enhance public service delivery, as well as expand communication channels for engagement and empowerment of people. The opportunities offered by the digital development of recent years, whether through online services, big open data, social media, mobile applications or cloud computing, are expanding the way for the development of e-Government [23].

World e-Government rankings are increasingly important as they guide countries' focus of their efforts. The e-Government rankings are in a process of maturation in that direction, moving from purely measuring web sites to assessing use and government qualities. There

are a number of indexes. Each model measures how ready a society or economy is to benefit from ICT. However, the range of tools uses widely varying definitions and different methods for measurement [14]. Some of them have become frequently cited and used as benchmarks, guiding the debate as well as governments' investments in e-Government [7]. In the EU, there is a series of the EU e-Government Benchmarking reports. This annual exercise started in 2001 and the 2014 report [3] is the eleventh measurement. These reports are mostly focused on the best performing countries that have implemented the most mature e-Government services. However, these countries cannot be compared in time, because the ranking system has changed over time. The last report is based on the e-Government Benchmark Framework 2012–2015 [3]. In a global perspective, frequently cited indexes include the United Nations (UN) e-Government rankings, the Economist's e-Government readiness index and Brown university's regular global e-Government studies [7], [14]. The e-Government Development Index (EGDI) by UN is broader than the EU's one by adding a social component. The Economist's index also measures government quality aspects. The Brown index is again more limited focusing on features of web systems, such as the existence of a privacy policy, security policy, advertisements and the opportunity to comment [7]. The last two indexes were not used in this research study, because there is a big time gap between the individual reports or they only cover selected countries.

1 Problem formulation and tools used

The main aim of this paper is to compare the progress of the information society and also macroeconomic indicators, which are represented by the EGDI and the e-Participation index (EPI), in the EU Member States between 2007 and 2013. This period is covered by the UN e-Government Surveys 2008, 2010, 2012 and 2014. The EGDI presents the state of e-Government development of the UN Member States. Mathematically, the EDGI is a weighted average of three normalized scores on the most important dimensions of e-Government, namely: provision of online services – Online Service Index (OSI), telecommunication connectivity – Telecommunication Infrastructure Index (TII) and human capacity – Human Capital Index (HCI). More about the weight calculation can be found in [20], [21], [22] or [23]. It is not designed to capture e-Government development in an absolute sense; rather, it aims to give a performance rating of national governments relative to one another [23]. The EPI is then derived as a supplementary index to the UN e-Government Survey. It is focused on the use of online services to facilitate provision of information by governments to citizens (e-information sharing), interaction with stakeholders (e-consultation), and engagement in decision-making processes (e-decision making). The maximum possible value of the EGDI as well as the EPI is one and the minimum is zero. The conceptual framework of the EGDI and the EPI remains unchanged since its inception in 2001 [23].

This paper also evaluates the influence of the financial crisis, which started at the end of 2007 and led to the global recession [6], [15], and the Eurozone crisis, that has been affecting the members of the Eurozone since early 2009 – more in [17], [18], on the progress of the EGDI and selected macroeconomic indicators. These were chosen based on the literature review – the real Gross Domestic Product (GDP) per capita, unemployment rate, inflation rate and total population of the EU Member States, which are closely related to the implementation of the e-Government services. States with deep impact of the financial crisis has increased governmental spending and enacted laws supporting the demand for key products industry [8]. Thus, this research study tries to find the answers to the following questions: What are the differences between the EU Member States through

the years? Are there still groups of the “old” and the “new” Member States? Which Member States are more similar to each other than to those in other groups? What is the most successful Member State? What are the most significant changes between the years 2008, 2010, 2012 and 2014?

The first part of this paper is based on literature review of foreign and domestic resources which led to make recommendations on the selection of macroeconomic indicators and other related attributes connected to the development of e-Government. The research study consists of correlation and cluster analysis over the set of obtained data. The last part contains results and recommendations for the further research. The main tools used are the statistical software Statistica 10 and Microsoft Excel 10.

2 Literature review and background

In recent years, most of the researchers have focused on the current state of the art of e-Government, the measurement of the e-Government services or relationship between e-Government and selected macroeconomic indicators, those characterize the state and efficiency of a national economy. Wilkinson and Cappel [24] utilized content and correlation analysis to determine whether the variables of economic prosperity and population had any significant effect on predicting the extent of country e-Government involvement. Their results showed a significant correlation between the variables. Therefore, the level of resources and size of a country appeared to be associated with the extent to which it delivered services via the web, meaning the larger a country was in terms of income and population, the greater was its e-Government involvement. Along similar lines, Mazengera in [13] used the correlation analysis to identify factors contributing to successful e-Government implementation. The study has revealed that there was the correlation between the internet use and the number of cell phones, but a very low correlation with the literacy level. However, it did not consider other softer aspects that may impact the uptake and use of e-Government services such as social background, income levels, etc.

Krishnan et al. in [9] showed that ICT infrastructure, e-Participation and human capital had a direct relationship with e-Government maturity. Their results also indicated that governance in a country, e.g. political stability, regulatory quality or control of corruption, did not significantly contribute to its e-Government maturity, and their relationship was not mediated by e-Participation. Špaček [19] stated that governments across Europe work with a mix of instruments aimed at enhancing the centralization of their e-government development through new centrally promoted infrastructures and services that allow for more integrated service delivery, virtual or physical, and through changes in organizational structures. Matei and Savulescu [12] analysed the current state of e-Government in the eleven Balkan countries based on data provided by UN e-Government Surveys. However, they only used the data from UN Surveys and highlighted the most important strategies and programmes without the connection to any macroeconomic indicator. Also Dumpe and Arhipova [2] analysed the EGDI changes in the period 2008–2012, as well as discussed the main factors influenced this index. Máchová and Lněnička [11] offered a comprehensive look at the state of e-Government services in the EU Member States in 2010. They used the data available before the beginning of the financial crisis, thus this research study may revise their findings and help to clearly compare the EGDI progress.

The quality of the EPI by validating it against other indexes of government-citizen relations qualities, democracy, internet filtering, and transparency was analysed by Grönlund [7]. The author found out that the relation between the EPI and indexes of democracy and participation was non-existent, even very undemocratic countries could score high on the EPI and countries whose severely obstructed citizen internet use by filtering could score high on the EPI by introducing technical tools on their web [7]. Mohammed and Ibrahim [14] revisited the existing e-Government indexes to show the main common indicators and proposed a preliminary framework to refine indexes' indicators according to the characteristics of the cloud computing. As a result, some indicators will get low weight in the index and others will get high weight or even new indicators or variables can by introduced. ICT infrastructure is considered as one of the main indicators to preparedness of a country to implement e-Government systems and it relatively has high weight in the current indexes. Thus, as infrastructure is hosted on cloud, government does not have to spend on hardware, software, skills resources and maintenance. Therefore, ICT infrastructure as a component of the index will get less weight [14]. Also the EU emphasizes the cloud computing technologies and big open data to provide flexibility and enable greater consistency in the public services [3].

Koťátková-Stránská and Lelek [8] analysed the similarity of the EU Member States on the evolution of selected variables (e.g. real GDP growth rate in %, employment rate in %, inflation rate in %, etc.) which can show the integration process success. They used cluster analysis and compared the data before and after the financial crisis (period 2004 –2008 and period 2009–2010). Their results showed that GDP growth rates significantly dropped during the crisis. Especially those, which had have the highest growth rate in the previous period (Latvia and Estonia). Public debt rose most in Ireland and Italy and most Member States do not meet the Maastricht criteria with long-term values of 60%. There are, however, still relatively few studies that have addressed the influence of the financial crisis in the context of e-Government.

3 Hypotheses statement

According to the above defined aim and the literature review author has formulated the following four hypotheses. Their validity will be examined by using multivariate statistical methods.

H1: There is a correlational relationship between the GDP per capita and the EGDI, but no correlational relationship between the GDP per capita and the EPI.

H2: After a decline captured in the UN report 2010, there will be an increase in the upcoming years 2012 and 2014.

H3: The decline of the EGDI in the "old" Member States in 2010 will be lower than in the "new" Member States in the following years.

H4: There is a similarity in the development of the Eurozone Member States and they will be clustered together in 2014.

4 Research study

Data analysis includes descriptive, correlation and cluster analysis was conducted. Statistical software Statistica 10 and Microsoft Excel 2010 were used.

4.1 Data preparation and descriptive analysis

Selected analyses were performed with Statistica 10, data pre-processing and the basic operations on them were conducted in Microsoft Excel 2010. The data used to test hypotheses outlined above came from the UN database [1]. The main documents used were the UN e-Government Surveys from 2008, 2010, 2012 and 2014. The other data came from Eurostat [5], which provides more actual data than UN. These data were from 2007, 2009, 2011 and 2013, because the reports always evaluated the state of e-Government from the previous year. The following attributes were chosen:

1. Total population,
2. Real GDP per capita (in €),
3. Unemployment rate (annual in %),
4. Inflation rate (annual in %),
5. Points for emerging information services (stage 1 in %) – part of the OSI,
6. Points for enhanced information services (stage 2 in %) – part of the OSI,
7. Points for transaction services (stage 3 in %) – part of the OSI,
8. Points for connected approach (stage 4 in %) – part of the OSI,
9. Estimated internet users per 100 inhabitants – part of the TII,
10. Main fixed telephone lines per 100 inhabitants – part of the TII,
11. Mobile subscribers per 100 inhabitants – part of the TII,
12. Personal computers per 100 inhabitants – part of the TII,
13. Total fixed broadband per 100 inhabitants – part of the TII,
14. Adult literacy rate (in %) – part of the HCI,
15. Gross enrolment ratio (in %) – part of the HCI,
16. EPI.

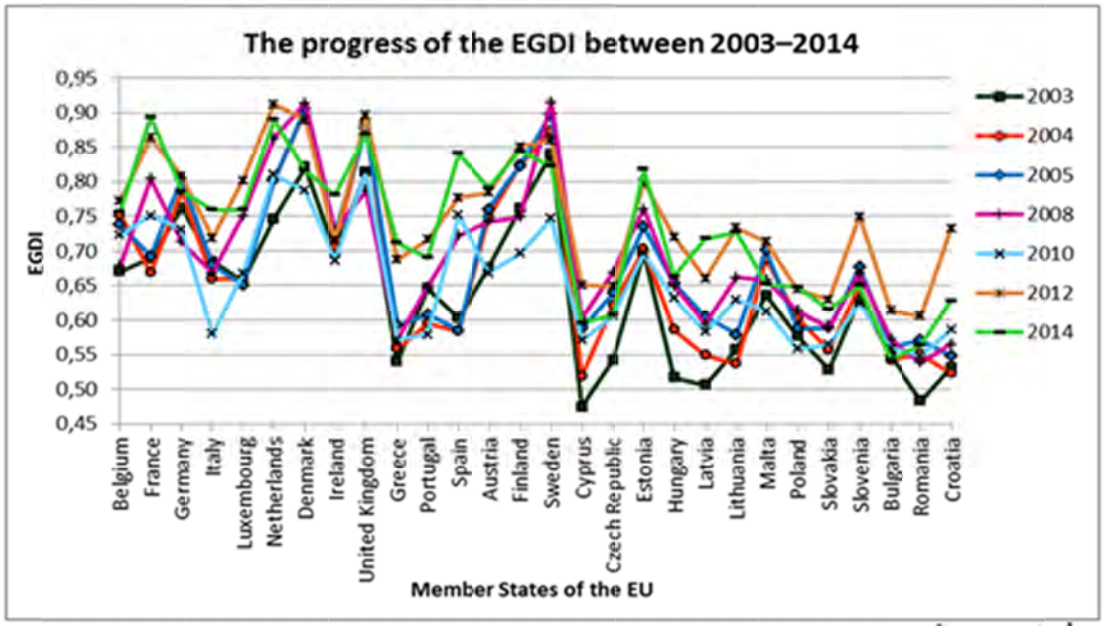
Firstly, only the data valid for the EU Member States in the evaluated years were selected. Then the attributes were copied into Microsoft Excel 2010 sheets for further processing and saved as a file named “data.xlsx”. The same data were also saved in Statistica 10 as four files named “data2008.sta”, “data2010.sta”, “data2012.sta” and “data2014sta”. In total, each data matrix consisted of 28 cases (EU Member States) and 16 attributes (variables). Finally, the data were formatted, i.e. unified the number of decimal places, a comma was chosen as a decimal mark, checking for missing and unreliable entries, etc. Descriptive analysis is needed to help visualize the data and get a sense of their values, i.e. plot histograms and compute summary statistics to observe the trends and the distribution of the data [10]. It was performed using the Data Analysis tool in Microsoft Excel 2010. Next step was the comparison of the relevant statistics between 2008, 2010, 2012 and 2014. It helped to form the basis of the initial description of the data as part of a more extensive statistical analysis, which will be followed later in this paper.

4.2 The progress of the EGDI between 2003–2014

Microsoft Excel 2010 was, among others, used to show the progress of the EGDI in 2003, 2004, 2005, 2008, 2010, 2012 and 2014. For the missing years, the interpolation

can be used [10]. The EU Member States are sorted by the year they joined the EU. In the same year of the accession, they are in the alphabetical order as it is shown in the Fig. 1. No other analysis was performed using data from the years 2003, 2004 or 2005.

Fig. 1: The progress of the EGDI between 2003–2014 in the EU Member States



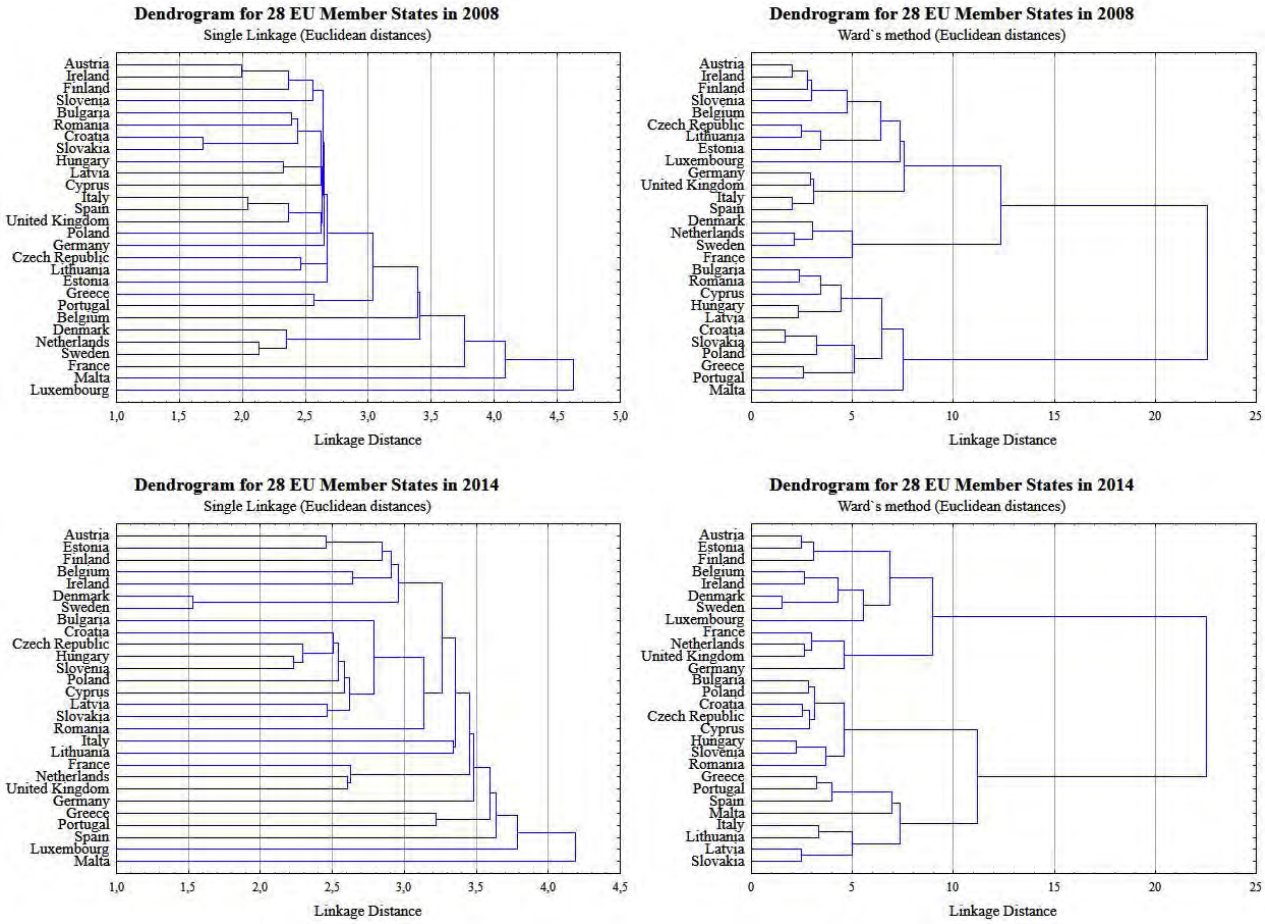
Source: Author

4.3 Correlation and cluster analysis

Correlation analysis was used to test the statistical significance of the relationship that may exist between the two variables. The results indicate an association between the predictor and criterion variables [10], [16]. The first data matrix was uploaded into Statistica 10, which made its standardization and subsequently performed cluster analysis based on the selected variables and parameters set for the clustering. But first, the variables had to be as independent from one another as possible. Therefore, the correlation matrix was tested to check if any of the variables are strongly correlated to eliminate any of the correlated ones. Correlations greater than 0,5 are statistically significant [10]. It happened in the case of the variables of the OSI and the TII for all the years, when the highest values were found in 2008. For this reason, the variables 6 and 7 were removed from matrices as well as the variable 10 (see section 4.1).

A non-hierarchical clustering K-means method and hierarchical algorithms have been applied. These methods belong to the group of unsupervised learning methods, and also clustering. In the case of K-means algorithm initial cluster centres are set first and then the samples, which are located within a given distance from the centre of the cluster, are assigned to the cluster [10], [16]. Thus, the next step here was the initial setup of the centres of the clusters, which was carried out using a hierarchical single linkage algorithm and Ward's minimum variance method, which enables the efficient functioning of the K-means algorithm and reduces the possibility of the error (utility) function being stuck at the local minimum [10], [16]. The Euclidean metric (distance) was chosen as a measure of dissimilarity. Fig. 2 then shows the dendrogram of the hierarchical single linkage algorithm and for the comparison also the dendrogram of the Ward's method, both for 2008 and 2014 data sets. Compared to the hierarchical single linkage algorithm the Ward's method provides a key contribution to the variance rather than the distance of the samples. This is reflected in the different shape of the dendrogram [16].

Fig. 2: Dendrograms for Single Linkage and Ward's method in 2008 and 2014



Source: Author

The non-hierarchical clustering was done by means of algorithm K-means for 3, 4, 5 and 6 clusters. From the given number the highest quality clustering proved to be clustering for 5 clusters (e.g. distances, no cluster with a single member, etc.). This value was selected for the further processing. The results for every year are shown in the Tab. 1. A member of each cluster with the longest distance from the centre is bold.

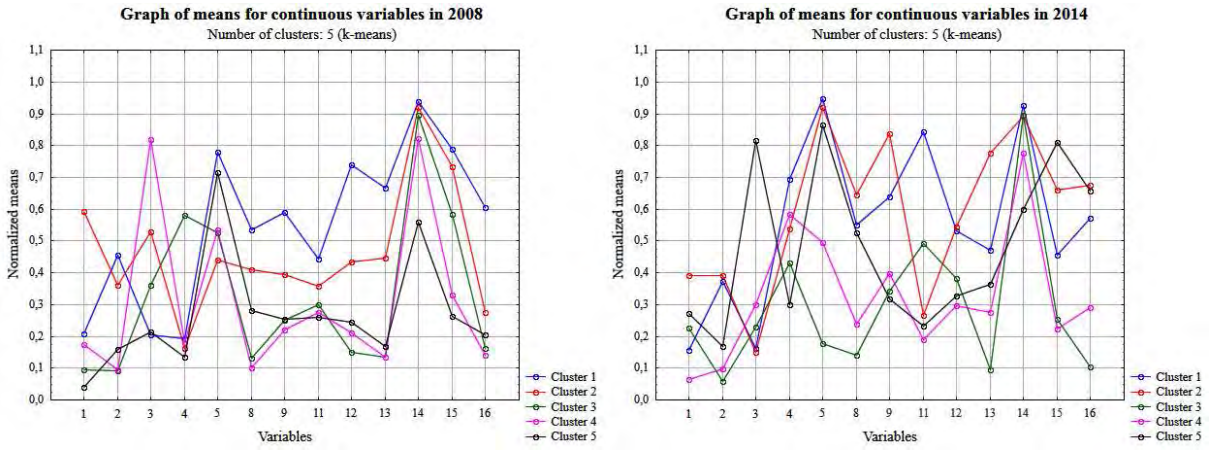
Tab. 1: Clustering in 2008, 2010, 2012 and 2014 using K-means algorithm

2008	2008	2010	2010
Cluster 1	**Cluster 3**	**Cluster 1**	**Cluster 3**
Austria	Bulgaria	Austria	Bulgaria
Denmark	Greece	Estonia	Czech Republic
Estonia	Hungary	Finland	Greece
Finland	Latvia	Ireland	Poland
France	**Lithuania**	Italy	**Portugal**
Ireland	Romania	**Luxembourg**	Romania
Luxembourg	Slovenia	**Cluster 2**	**Cluster 4**
Netherlands	**Cluster 4**	Belgium	Croatia
Sweden	Croatia	Denmark	Hungary
United Kingdom	Poland	France	Latvia
Cluster 2	**Portugal**	Germany	Lithuania
Belgium	Slovakia	Netherlands	**Slovakia**
Germany	**Cluster 5**	Slovenia	**Cluster 5**
Italy	Cyprus	**Spain**	Cyprus
Spain	Czech Republic	Sweden	Malta
	Malta	United Kingdom	
2012	**2012**	**2014**	**2014**
Cluster 1	**Cluster 3**	**Cluster 1**	**Cluster 3**
Austria	Bulgaria	Austria	**Bulgaria**
Estonia	Romania	Estonia	Czech Republic
Finland	**Cluster 4**	Finland	Poland
Germany	Croatia	Italy	**Cluster 4**
Italy	**Greece**	Lithuania	Croatia
Lithuania	Portugal	**Luxembourg**	Cyprus
Luxembourg	**Cluster 5**	**Cluster 2**	Hungary
United Kingdom	Cyprus	Belgium	Latvia
Cluster 2	Czech Republic	Denmark	**Malta**
Belgium	Hungary	France	Romania
Denmark	Latvia	**Germany**	Slovakia
France	**Malta**	Ireland	Slovenia
Ireland	Poland	Netherlands	**Cluster 5**
Netherlands		Sweden	Greece
Slovenia		United Kingdom	Portugal
Spain			**Spain**
Sweden			

Source: Author

Another output of K-means is the graph of means for variables. The selected graphs are shown in the Fig. 3. Numbers of variables on the x-axis can be seen from the list of the attributes in the section 4.1.

Fig. 3: Graphs of means for variables in 2008 and 2014



Source: Author

5 Results and discussion

Based on the results of the descriptive analysis, the mean value of the GDP per capita has increased about 3% between 2008 and 2014 as well as the range between the largest and smallest values (more than 5%). The biggest difference between these two years is in the unemployment rate. The mean value has increased about 70% and the range about 200%. There is also a decline between 2008 and 2010, only the mean value of the mobile subscribers per 100 inhabitants has increased. The mean value of the EGDI has increased about 15% (the EPI even about 75%) from 2008 to 2014 and the range has decreased about 5% (the EPI more than 16%), which means that the differences in the e-government development between the EU Member States are minor through the years.

When testing whether there is a relationship between the GDP per capita and the EGDI, the results show that the GDP per capita has a correlational relationship with the EGDI at the significance level $p < 0,05$ where p-value is a measure of statistical significance [10]. However, it has been slightly decreased from 0,65 in 2008 to 0,59 in 2014. Also the UN stated that the income level of a country is a general indicator of economic capacity and progress, which influences its e-Government development. Access to ICT infrastructure and the provision of education, including ICT literacy, are related to the income level of a nation [23]. There is no significant correlational relationship between the real GDP per capita and the EPI. Correlation coefficient is only between 0,2–0,3 through the evaluated years. As a result, H1 is supported.

As can be seen from the Tab. 2, after a decline captured in the UN report 2010 [21], there was an increase in 2012, but in 2014 there was a decrease again. As a result, H2 is rejected. Also H3 is rejected, because the decline of the EGDI in the "old" Member States (EU15) in 2010 was higher than in the "new" Member States (EU13).

Tab. 2: A percentage change of the EGDI in the evaluated years

Group of the EU Member States / year	Percentage change of the EGDI versus the previous period			
	2008 [%]	2010 [%]	2012 [%]	2014 [%]
EU28	1,17	-5,52	14,29	-2,43
EU15	1,02	-6,17	14,09	-0,32
EU13	1,37	-4,57	14,56	-5,31

Source: Author

The results of the Ward's method in 2008 suggest that the EU Member States can be divided into two large clusters and a cluster with Denmark, Netherlands, Sweden and France. This cluster of four had a very low unemployment and inflation rate, but very high points for emerging information services and the EPI. These four Member States joined in 2010 the first large cluster, which is mostly consists of the "old" Member States together with Estonia and Slovenia. These two "new" Member States have achieved very good results in e-Government in the past years, they also belong to the Eurozone. However, in 2014 Slovenia has dropped in most of the evaluated variables. The second large cluster in 2010 is formed by the "new" Member States together with Greece and Portugal. These states together with Spain were affected by the financial crisis and the Eurozone crisis very deep. Therefore, they were clustered to one group in 2014, which was also confirmed by the use of the K-means algorithm. This group is defined by a very high unemployment rate, relatively low number of estimated internet users and total fixed broadband per 100 inhabitants. Based on the graph of means for variables, also the total population size has positive influence on the clustering (e.g. due to economies of scale or cloud computing).

The results of the Ward's method in 2012 suggest that the EU Member States can be divided into at least four smaller clusters. The biggest differences between the EU Member States were found in this year. Also two very small clusters were formed using K-means algorithm in 2012 and the distances from the centre within the clusters were larger than in 2010 or 2014. Consequently, this period between 2010 and 2011 covered by the UN report 2012 [22] was characterized by the increase of the unemployment and inflation rate, decrease of the GDP per capita and the OSI, which is closely connected to the government's investments. The results also show similarity in the Eurozone. In 2014, all the members were in the clusters 1, 2 and 5, except Lithuania, which is only in the European Exchange Rate Mechanism (ERM II), and Denmark, Sweden and United Kingdom, which obtained special opt-outs in the original Maastricht Treaty. As a result, H4 is supported.

Conclusion and future research directions

The main aim and partial steps were completed successfully. The results obtained using the statistical methods indicated that there was a decline in 2010 and again in 2014, where the decrease was more significant in the "new" Member States. Based on the results it can be concluded that the continuing stagnation has affected mainly the EU Member States in southern Europe. Although Croatia did join the EU on 1st July 2013, the strong similarity to the other Member States was found in 2008, 2010 as well as in 2012. Considering the development of e-Government in the Czech Republic through the evaluated years, it is characterized by the low inflation and unemployment rates, only average availability of online services and relatively high numbers of internet users and mobile subscribers per 100 inhabitants. The other Member States with the quite similar values are Bulgaria, Malta and Poland. The most successful EU Member States were in 2008 in cluster 1, in 2010 in cluster 1 and also cluster 2 as well as in 2012, and in 2014 in cluster 2 headed by Denmark.

Otherwise, the uptake of e-Government services, especially parts of the TII, which implies past public investment in delivering such services, may increases the relative probability of the lower unemployment and inflation rate. The clustered groups of the EU Member States with the measured similarities may be used in the context of the financial instruments of the EU's Regional policy or the Digital Agenda to set new and more stringent targets and requirements for this funding period in terms of quality, openness

and completeness. Also the other European states could be clustered together with the EU Member States. There are clear opportunities for the future improvement of e-Government, including technology trends towards, e.g. social media and mobile devices and technology which are inherently interactive, as well as cloud computing.

For the future research methodology it was confirmed that Ward's method provides an appropriate mechanism for the connection of variables into the appropriate clusters as the most common grouping of the EU Member States based on the level of the EGDI and the related macroeconomic indicators. Also, further research could focus on the determinants not only of the total amount of money devoted to e-Government services but also of the strategic choices that EU Member States have done.

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